**Attentional capture: Biological relevance, multisensory stimulation, and consciousness**

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The authors Ruz and Lupiáñez are to be commended for a thorough overview of many of the key studies in the attention capture literature. In the present commentary we would like to suggest three lines along which future attention capture research might be broadened: (1) the role played by biologically relevant stimuli; (2) the role played by multisensory stimulation, and (c) the role played by consciousness.

Attention capture research has focused almost exclusively on the interplay between primitive features of visual stimuli, such as shape (circle, square, diamond, etc), color (red, green, blue, etc), and luminance (abrupt onset, abrupt offset, ramped onset, etc). And as the excellent review by Ruz and Lupiáñez has established, the conditions under which primitive features of this sort can capture visuospatial attention are quickly becoming well understood. However, there is also a new and growing body of research which suggests that reflexive orienting of visuospatial attention may also turn on the extent to which a stimulus is, or is not, biologically relevant. For instance, Kingstone and Friesen (1998), Langton and Bruce (1999), Driver et al. (1999) have each shown that presenting a picture of a face that has the eyes and/or the head turned to the left or right will produce a shift in spatial attention to the gazed-at location -- even when participants are instructed to ignore the gaze cue and are informed that the cue does not predict where a visual target will appear. These findings, coupled with the observation that the effect can emerge as soon as 100 ms after cue onset, demonstrate that the effect is reflexive in nature. Importantly, this orienting produced by a biologically relevant stimulus has several unique characteristics that differentiate it from non-biologically relevant stimuli. First, eye direction produces a shift in attention away from the location of the cue itself (i.e., the eyes) and a shift in attention toward the location that is being gazed-at. This contrasts with the standard attentional capture finding whereby attention is drawn towards the capturing stimulus. Second, the beneficial effect that gaze direction has on response latency lasts longer than anything that is observed normally with a peripheral non-informative cue. Namely, response time (RT) to a target can be facilitated with cue-target intervals of 1000 ms or more when the attentional cue is directed gaze, but facilitation does not normally extend beyond cue-target intervals of 200-300 ms when attention is drawn, say, to an abrupt peripheral onset. Finally, shifting attention reflexively to a gazed-at location has failed to produce any evidence that it results later in an inhibitory effect emerging at the gazed-at location. In other words, unlike primitive stimulus features normally studied by attention capture researchers, gaze direction does not appear to result in the inhibition of return phenomenon. Indeed recent work by Friesen, Ristic and Kingstone (submitted) suggests that facilitation by gaze direction, and inhibition of return, are dissociable effects that can co-occur. In sum, these findings suggest that reflexive orienting or spatial attention in response to biologically relevant stimuli may represent a new and unique form of attentional capture. Whether this form of orienting is

amenable to endogenous modulation in a manner similar to capture by simple features is a subject of future research.

As the authors correctly note at the outset of their paper,-a multitude of stimuli reach our senses at any given moment. However, this rich stimulation is by nature not constrained to one single sensory modality, but rather it is composed of a constellation of stimuli reaching different senses. There is a growing appreciation among researchers that attentional selection is best understood within a multisensory framework, superceding those of merely visuospatial attention (see Spence & Driver, 1998, for a review). Indeed, attentional capture across stimulus modalities in the form of reflexive shifts of attention have sometimes been proposed as an account for multisensory integration phenomena in the spatial domain such as the ventriloquist illusion whereby an auditory stimulus is mislocalized toward a concurrent visual event. Here, a reflexive shift of visual spatial attention is thought to capture auditory spatial attention (see Caclin et al., 2002; Macaluso, Frith & Driver, 2000; McDonald, Teder-Sälejärvi, & Ward, 2001; and Macaluso, Frith, & Driver, 2001, for a recent discussion). Importantly, this type of capture between sensory modalities appears to generalize to a number of modality combinations (i.e., touch and vision, touch and audition) and across the spatial and the temporal domains (Caclin et al., 2002; Soto-Faraco et al., in press). The conclusions reached by Ruz and Lupiañez´s review raise many interesting questions for future research on attentional capture across stimulus modalities. For example, whether a sensory modality can by itself serve as a "capturing" dimension, and whether a sensory channel can be established as a filter thereby permitting endogenous processes to modulate capture. Opening the field of attentional capture to a multisensory framework will undoubtedly improve our understanding human information processing in real world environments.

Finally, an intriguing question that Ruz and Lupiáñez touch on concerns the link between attentional capture and that of conscious awareness. For the most part attentional capture research has sought to determine the boundary conditions under which different types of primitive features do (or do not) capture attention and what role (if any) attentional goals play in capture. In most studies attentional capture is inferred from an increase in RT to respond to a task relevant target as a function of the presence of one or more unique distractors in the display. One seemingly important question that has yet to be resolved concerns the degree to which attentional capture by unique distractors co-occurs with awareness of the attentional capturing stimuli. We would conjecture that many researchers implicitly assume that once a stimulus captures attention, the stimulus is consciously perceived. This however could be incorrect and may exaggerate the putative link between attentional orienting and awareness. It may be possible that stimuli that use attentional resources do not always reach awareness. Several recent studies support this view. First, in a study of patients with visuospatial neglect, Danziger, Kingstone and Rafal (1998) found that visuospatial attention is drawn to the location of a cue for which there is no visual awareness. In this experiment target detection was facilitated for targets that appeared at a cued location despite the fact that subjects were not aware of the cues (see also Kentridge et al (1999) for further evidence of dissociations between attention and awareness in patient populations). In a study with healthy subjects McCormick (1997) found further evidence for spatial orienting without awareness, whereby visually degraded cues, of which subjects were not aware, affected orienting behavior to a subsequent target. For example, in one experiment the cues did not indicate the correct target location, yet target processing was facilitated at the cued location. And in another

experiment, in which the target typically appeared at the location opposite that of the cued location, RTs were faster when the target appeared at the likely target location than at the cued location. Finally, and possibly of most relevance for the attentional capture literature, Theeuwes et al. (1998), and Kramer et al. (2000) have shown that the eyes can be drawn toward the location of an abrupt onset before landing on a target elsewhere, and yet participants appear to have no conscious awareness of moving their eyes to a distractor by mistake. Taken together, these studies indicate that attentional orienting to a stimulus need not always co-occur with awareness of the attentionally grabbing stimulus.

In summary, the attentional capture research has made many significant steps forward recently, as the review by Ruz and Lupiáñez has clearly demonstrated. In the future there lie ahead many important and exciting lines of research for investigation.

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